Electronics for Dark Matter Detection

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Directional Recoil Identification From Tracks (DRIFT) Collaboration

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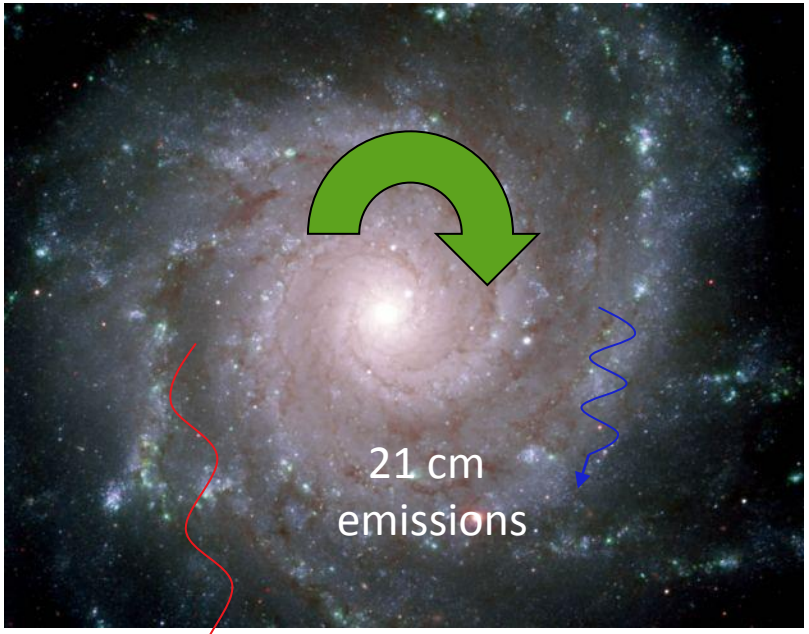
The Missing Mass

Dynamics of galaxy clusters

- X-rays from gas in clusters
- Dynamics of galaxy clusters
- Rotational speed of galaxies
- Gravitational lensing

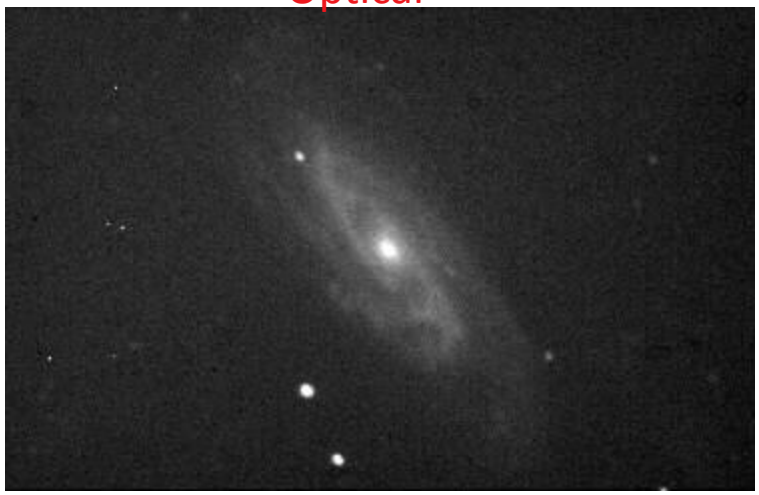
Large Scale Rotation



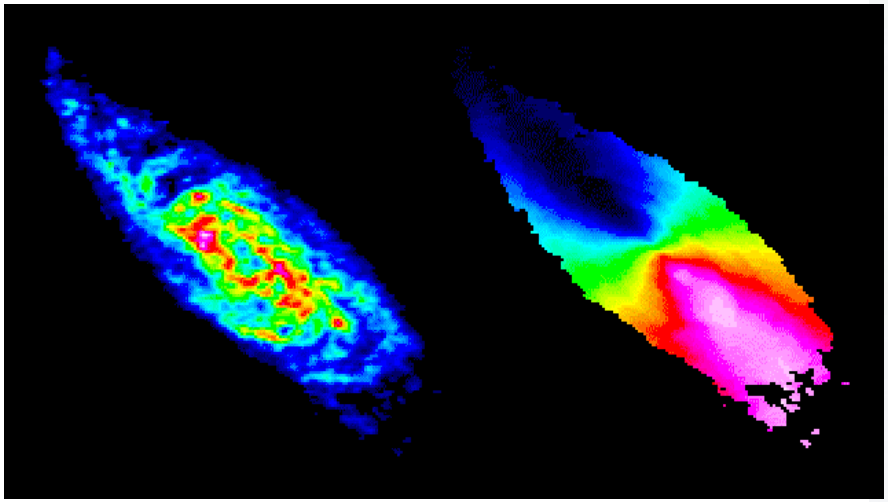
Doppler shift measurements at 21cm indicate that spiral galaxies rotate.

NGC 3198

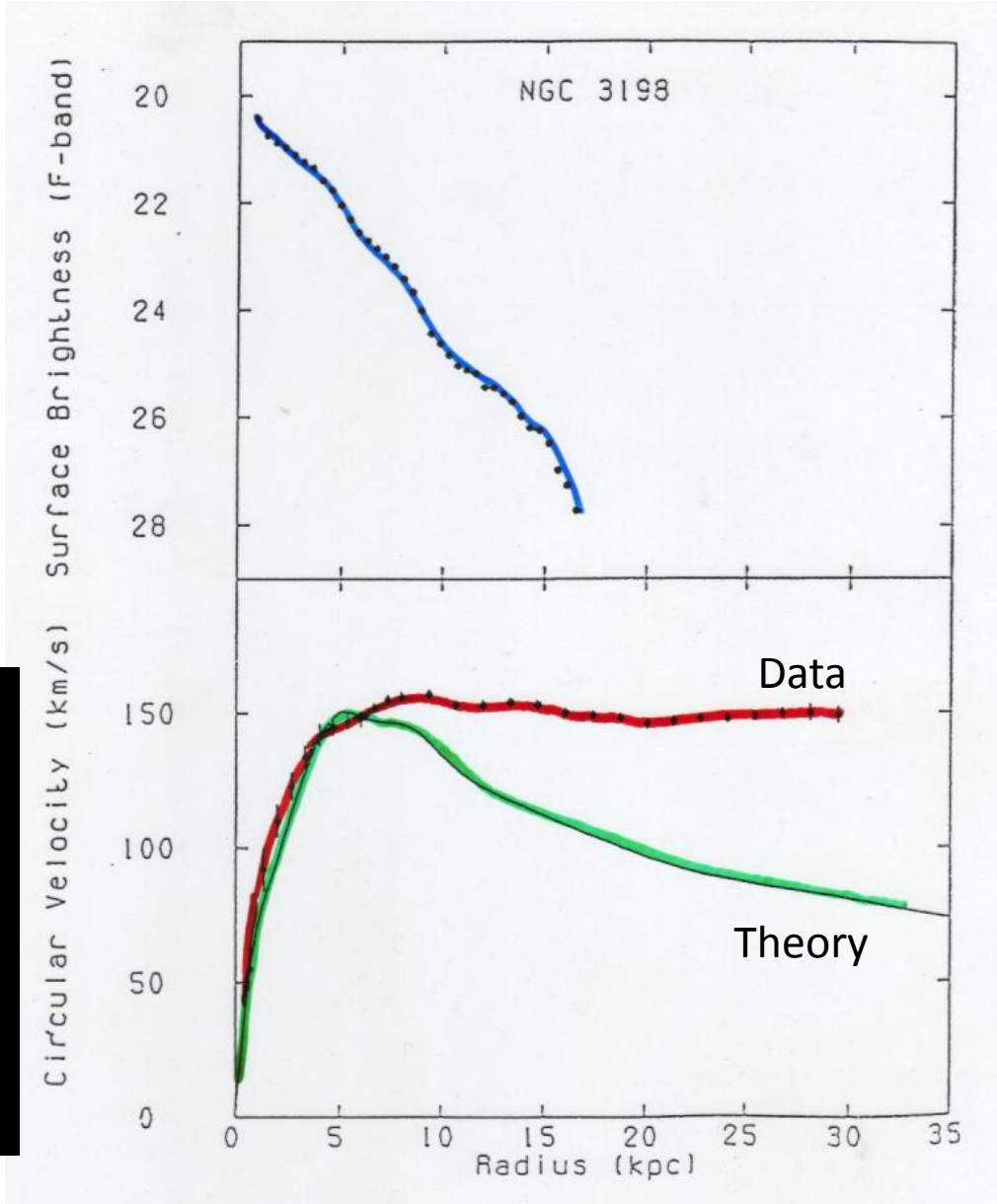
Optical



21 cm



Rotation Curve Measurements



Dark Matter Candidates

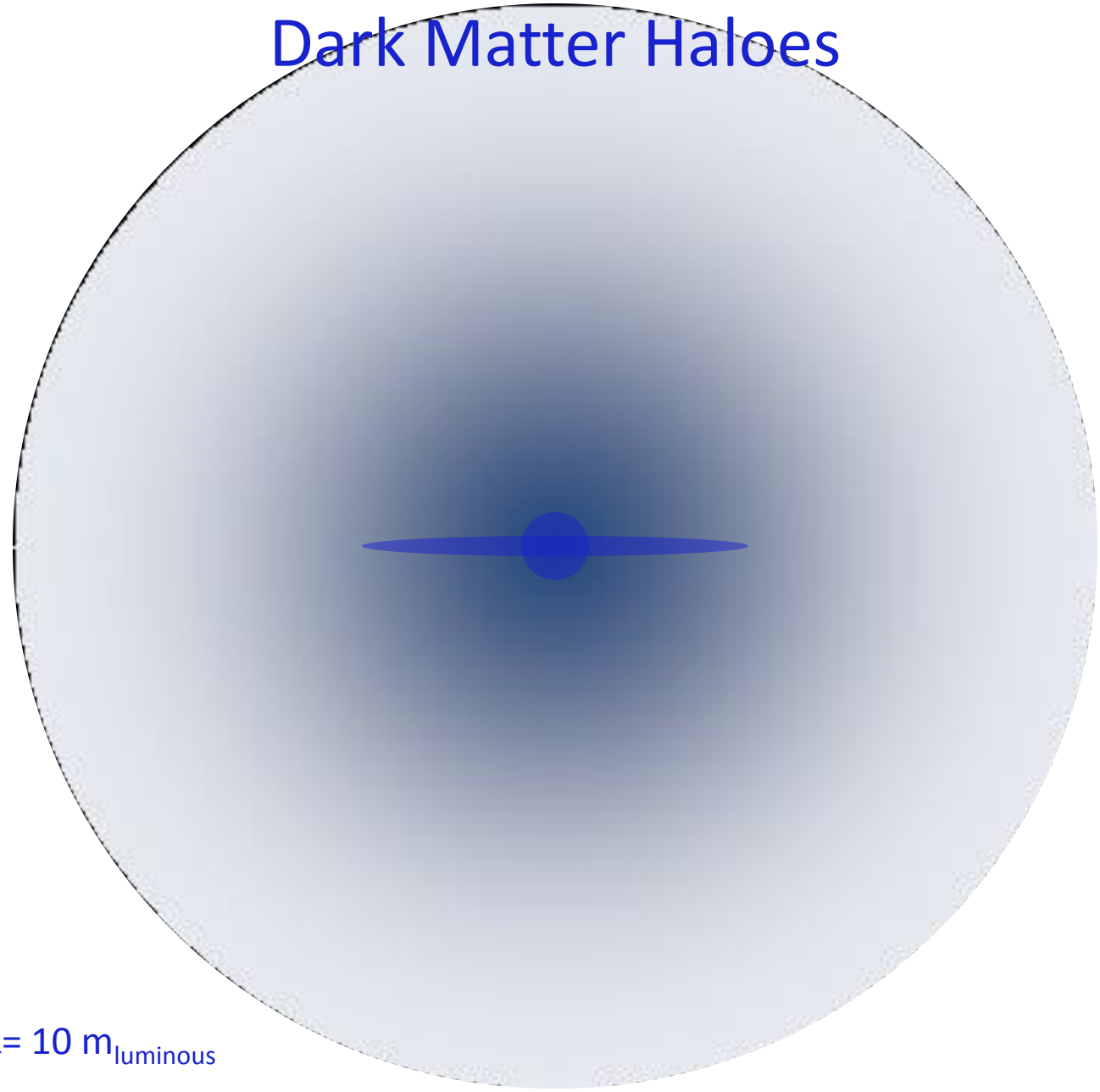
Axions

- $10^{-11} m_e < m < 10^{-9} m_e$
- Solves strong CP problem from particle physics

WIMPS

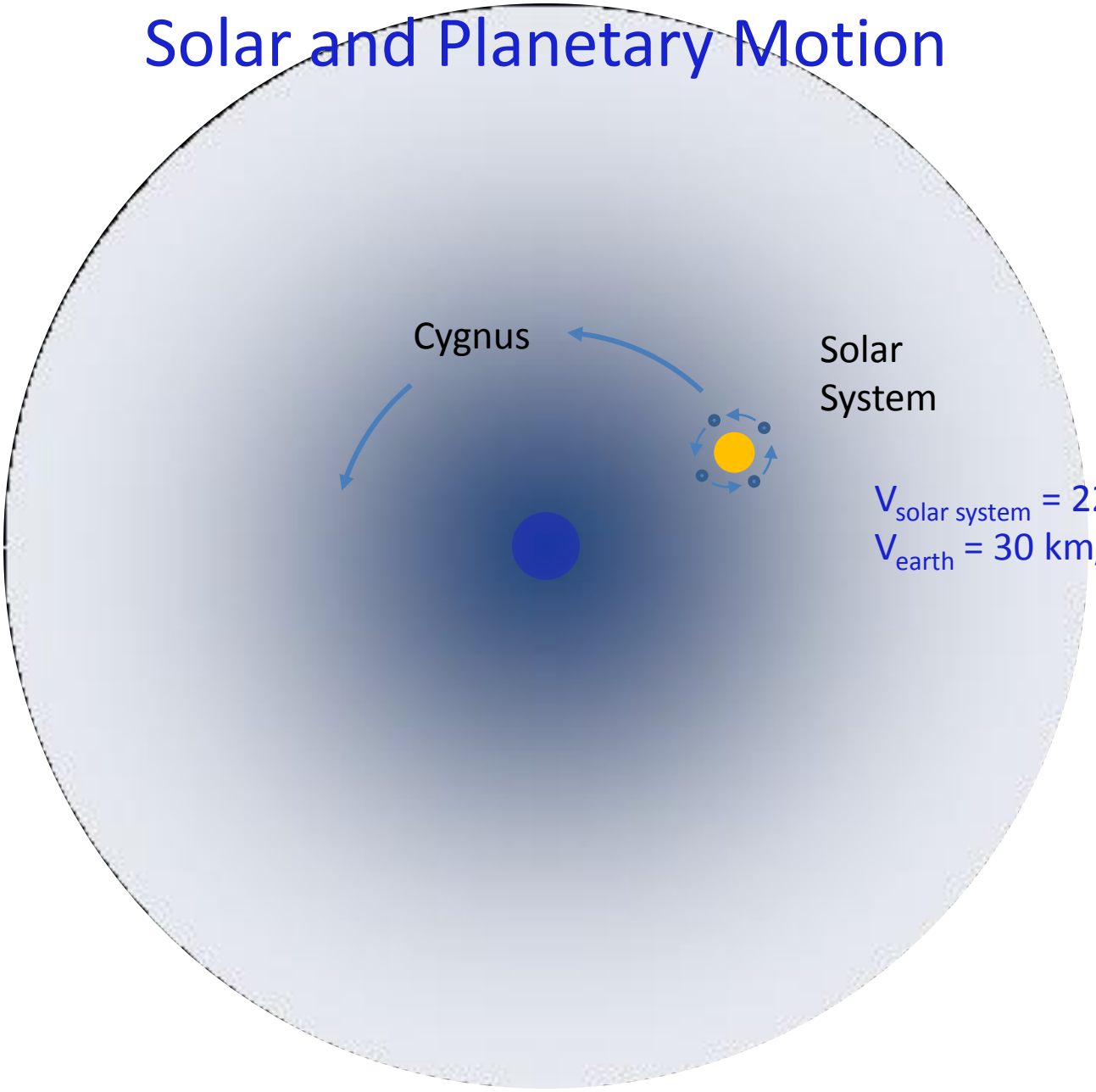
- Weakly Interacting Massive Particles (WIMPs)
  $10\ m_p < m < 10^4\ m_p$
- Weak interaction predicted for relic particles from the big bang.
- WIMPs are also motivated by supersymmetry.

Dark Matter Haloes

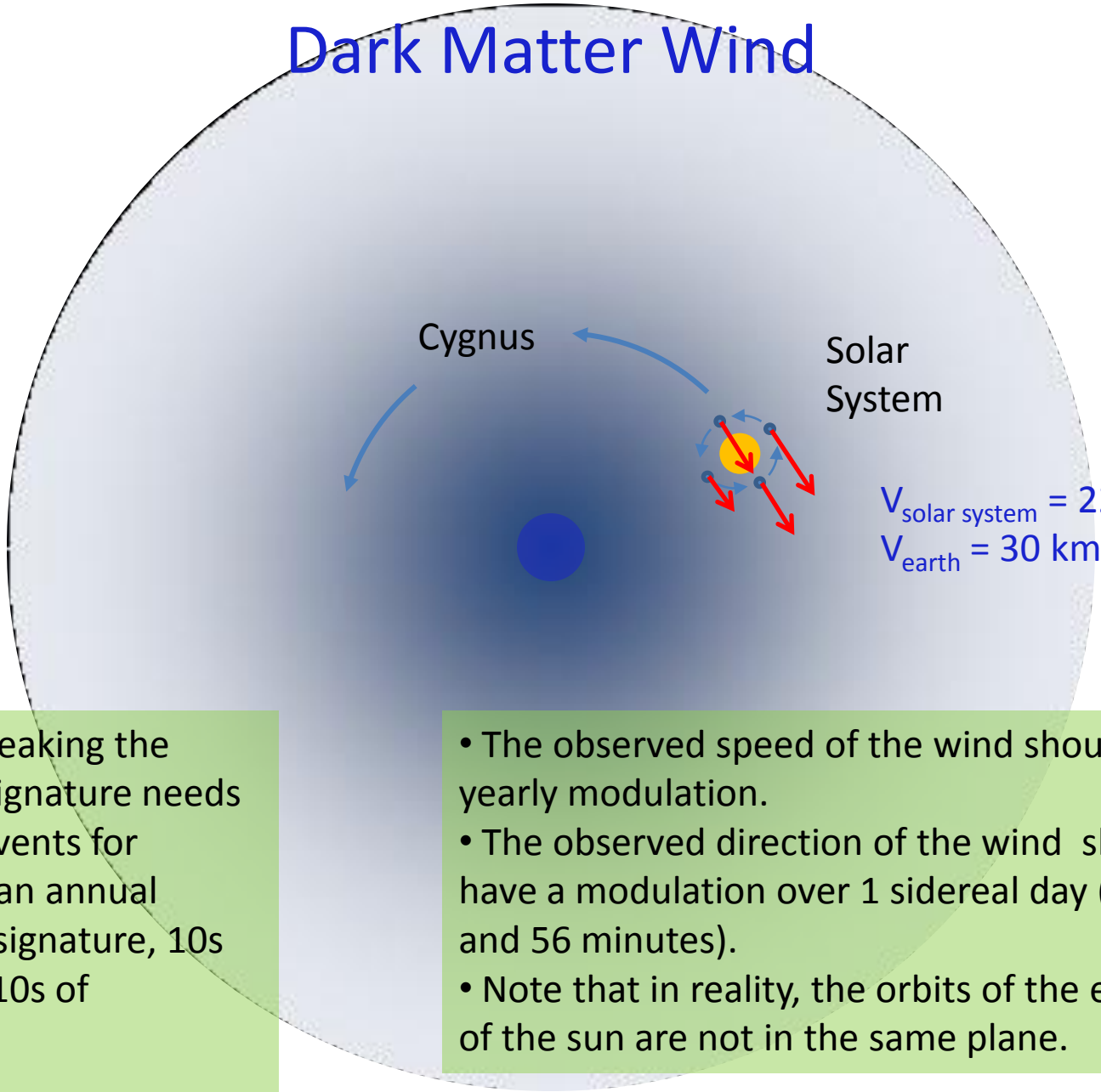


$m_{\text{dark matter}} = 10\ m_{\text{luminous}}$

Solar and Planetary Motion



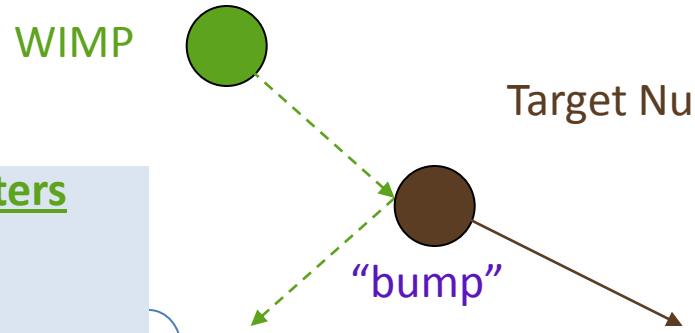
Dark Matter Wind



Generally speaking the directional signature needs 1000x less events for detection than annual modulation signature, 10s rather than 10s of thousands.

- The observed speed of the wind should have a yearly modulation.
- The observed direction of the wind should have a modulation over 1 sidereal day (23 hours and 56 minutes).
- Note that in reality, the orbits of the earth and of the sun are not in the same plane.

Direct Detection of WIMPs



WIMP parameters

Mass
10GeV – 10TeV

Mass Density
.3GeV/cm^3

Velocity
220 km/sec

Cross-section
Spin Independent:
$\sigma_{SI} < 10^{-44}$ cm^2

Spin Dependent
$\sigma_{SD} < 10^{-38}$ cm^2

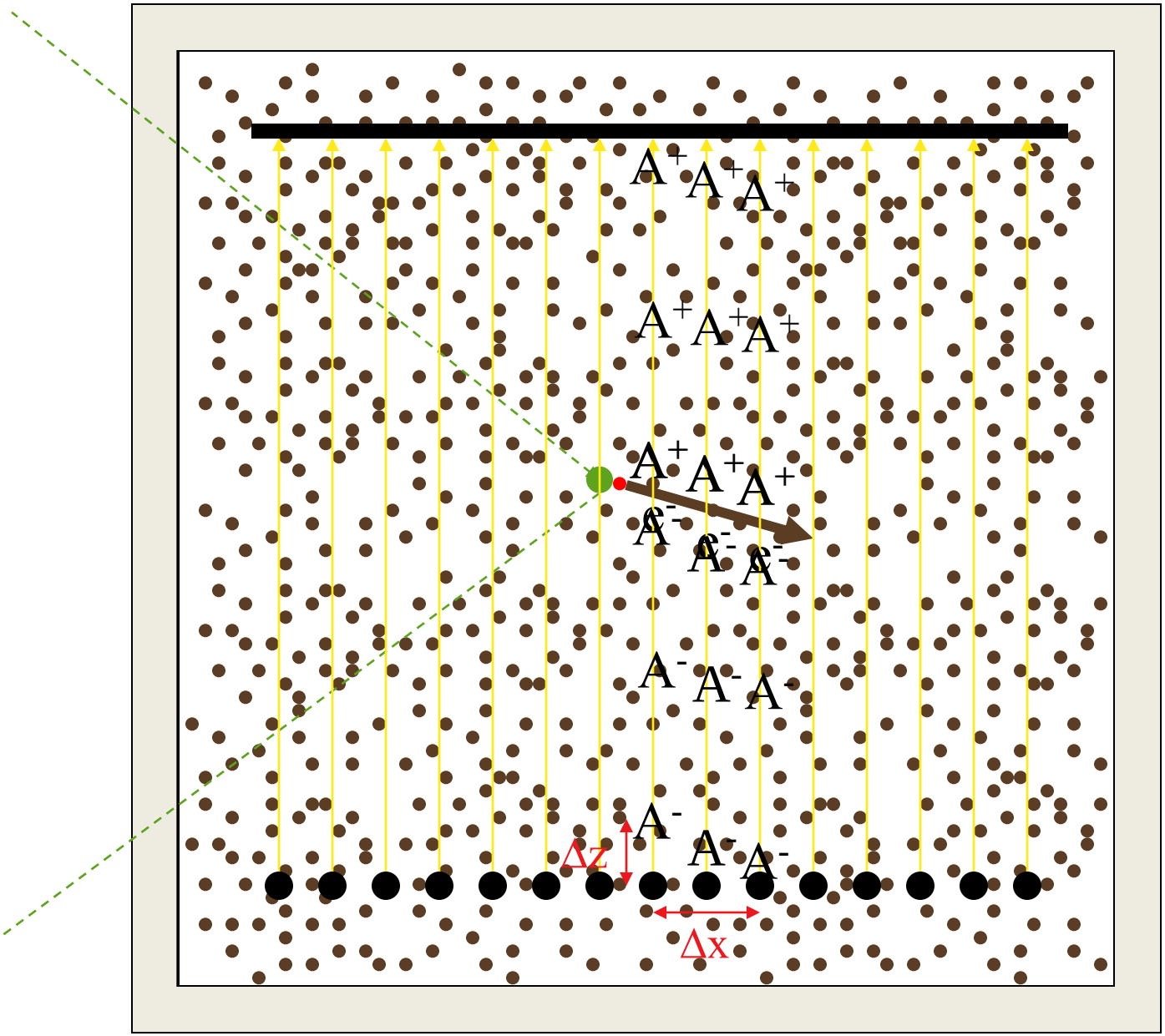
Flux = $10^3 - 10^6$
WIMPS/cm^2/s

Detector parameters

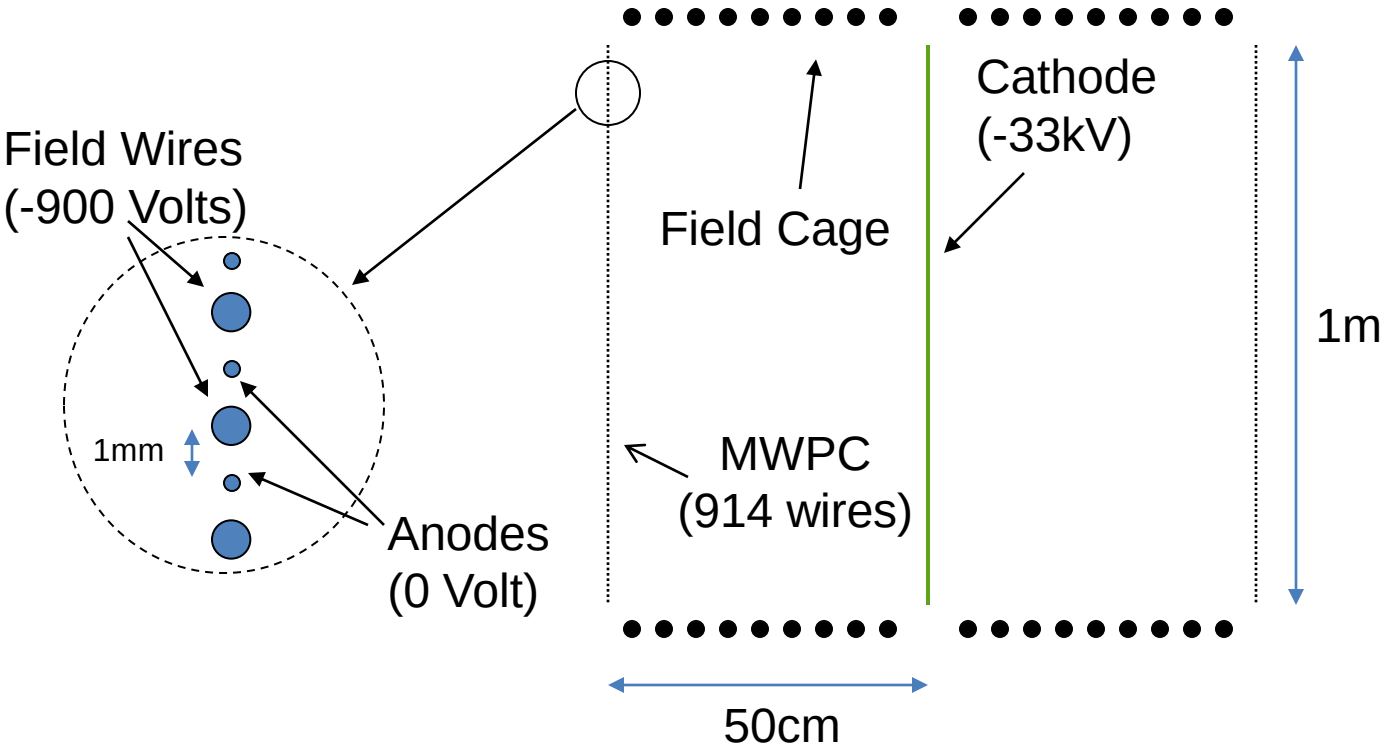
Recoil Energy
~kev/amu

Event rate
1 / kg / day *
$(\sigma/10^{-35}\text{cm}^2)*(100\text{GeV/m})$

The DRIFT Concept



The Drift-IIe detector



Low Diffusion in CS2

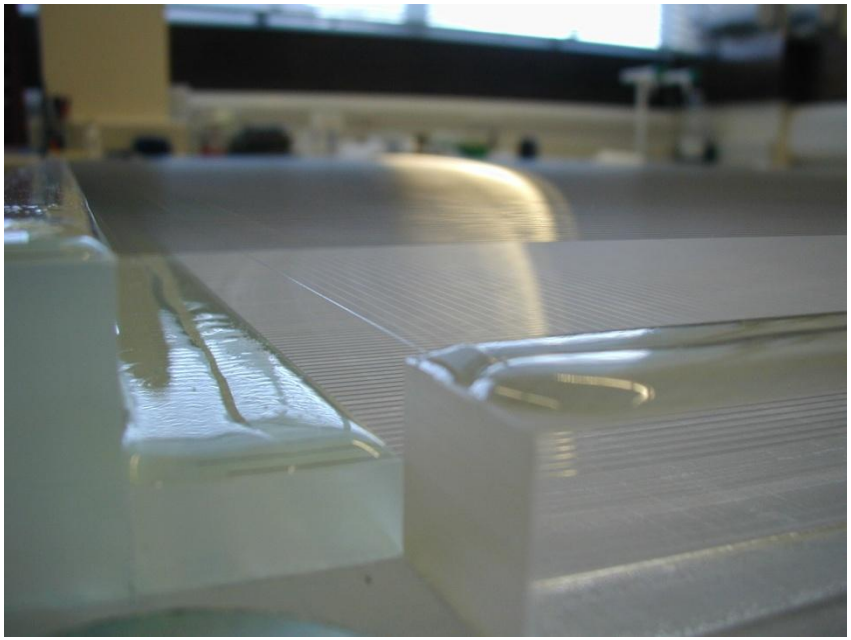
$$\sigma = \sqrt{\frac{2kTL}{eE}}$$

DRIFT Operating Parameters

E_{drift} = 600 V/cm
T = 300 K
L = 50 cm
v_{drift} = 60 m/s
t_{drift} = 0 - 8.33ms
$\sigma_{diffusion}$ = .65 mm
σ_t = 0 – 10 μs

DRIFT – Directional Recoil Identification From Tracks

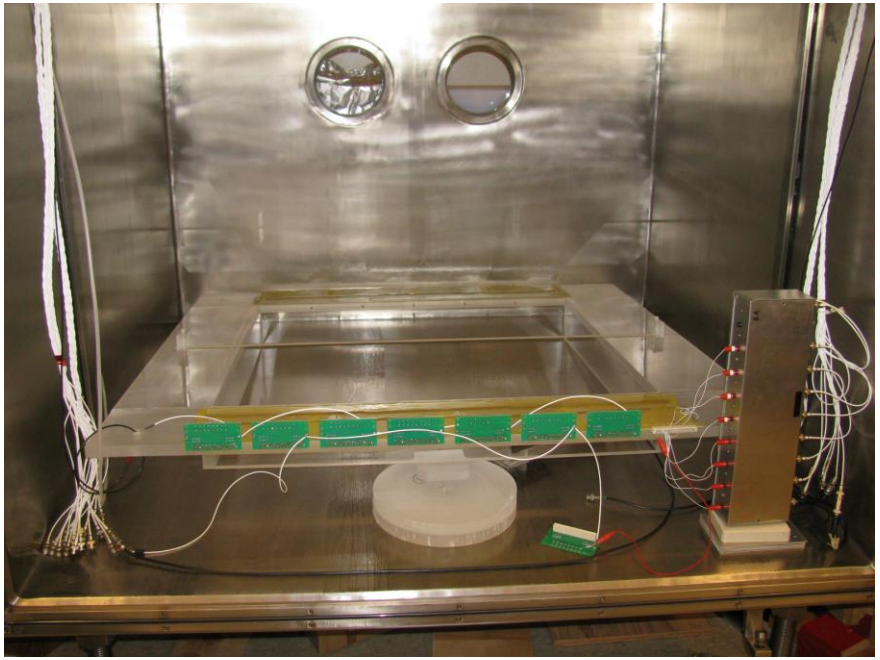
Started = 1998, US/UK
Underground in Boulby, England in 2001
Current operating detector = **DRIFT-IId**
Technology = Negative ion TPC with
MWPC wire readout



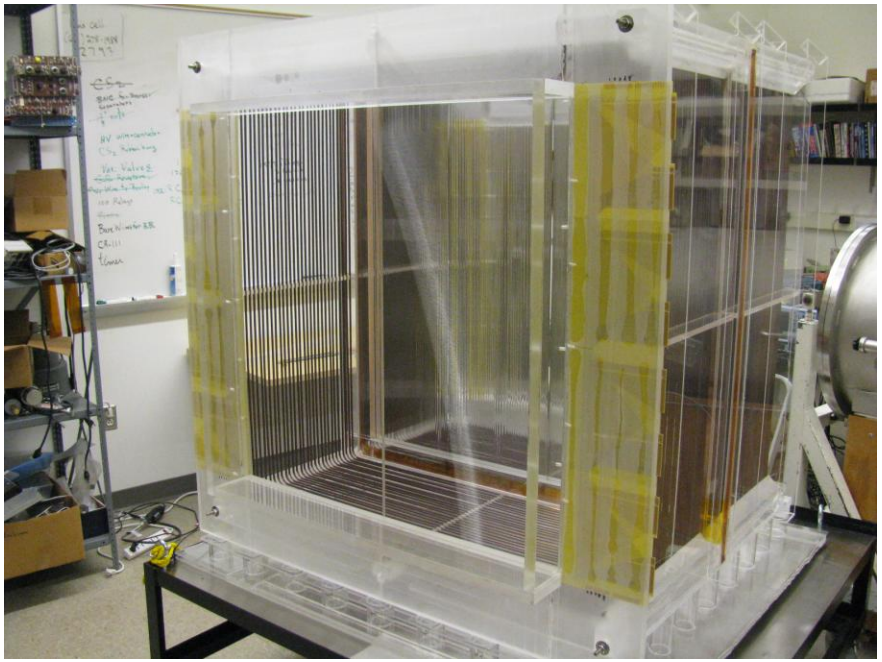
xyz resolution = 2 mm, ~<2mm, 0.2 mm,
no absolute
Target = 30 Torr CS_2 + 10 Torr CF_4
Fiducial volume = 800 liters
F mass = 33.3 g
Limit setting threshold = 50 keVr

New MWPC

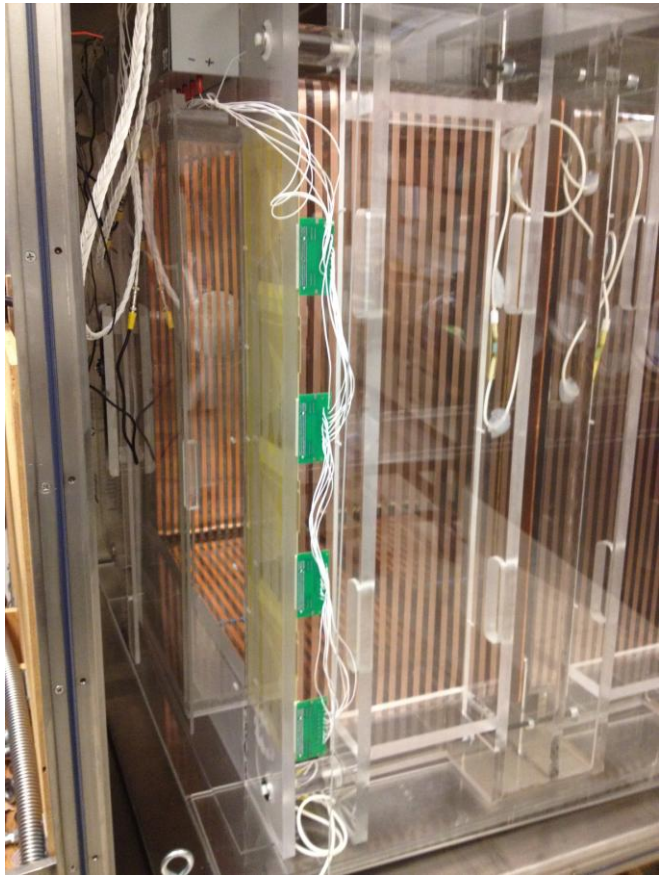
Testing the new MWPC at Oxy

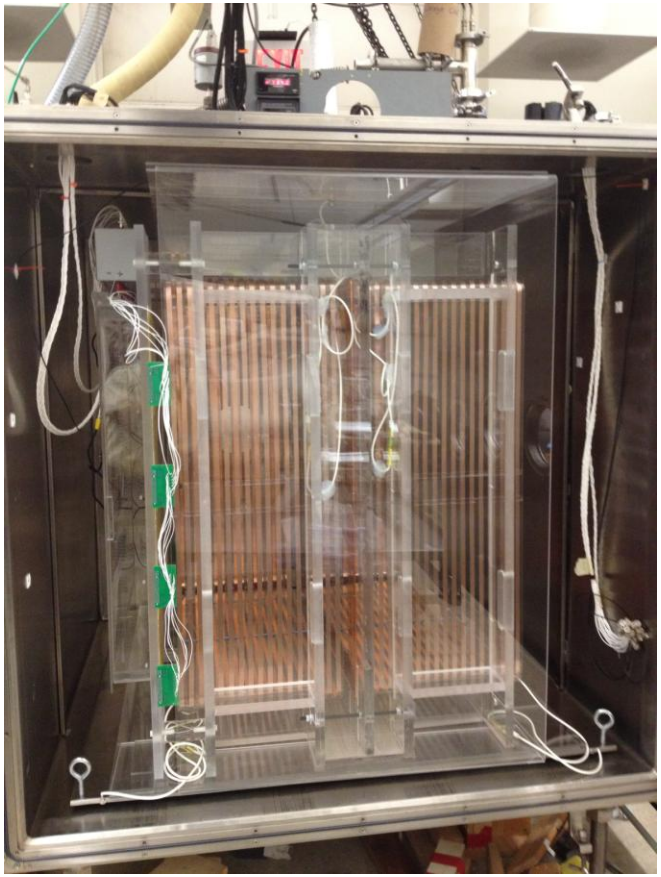


New MWPC on Field Cage

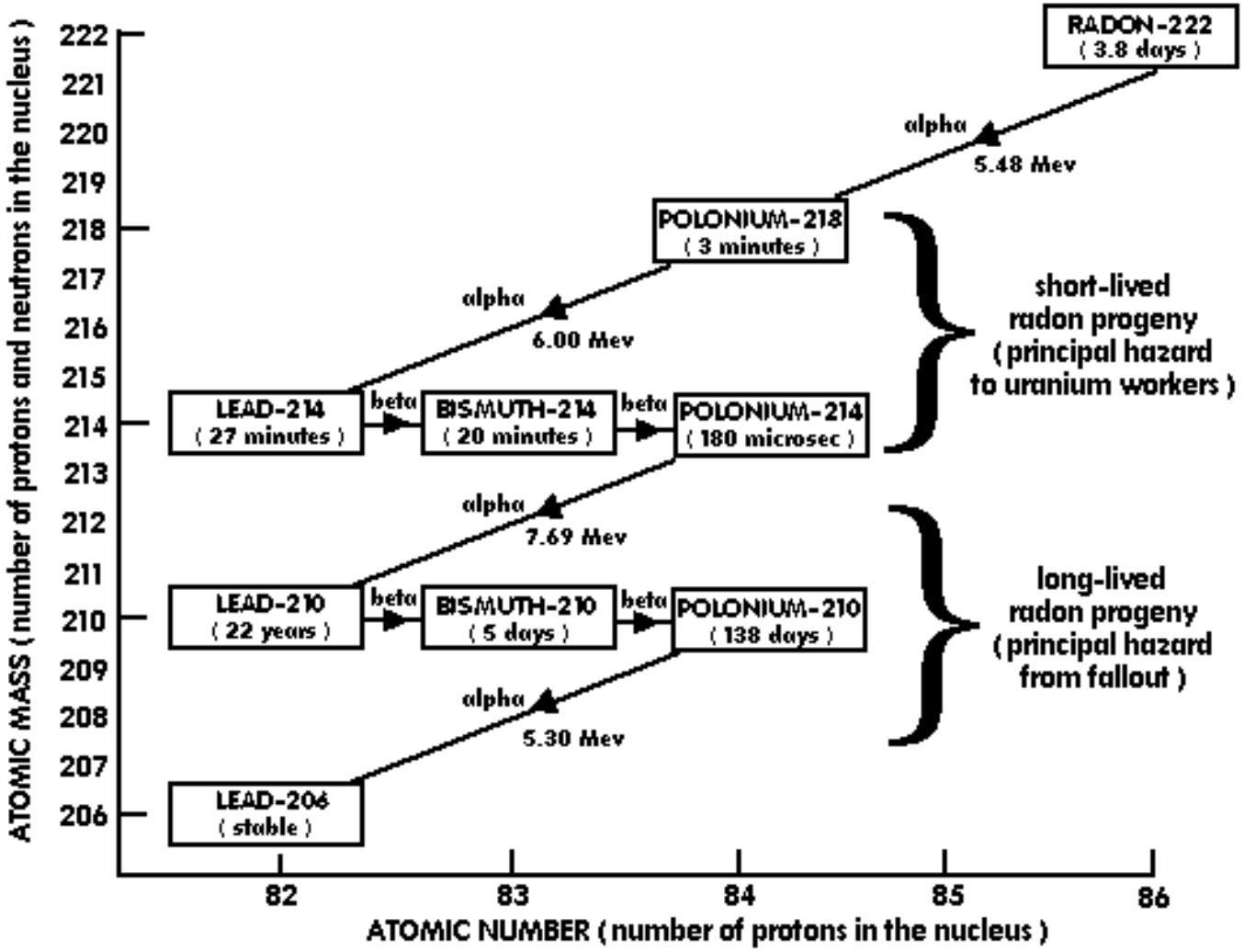


Detector with New MWPC ready for Testing

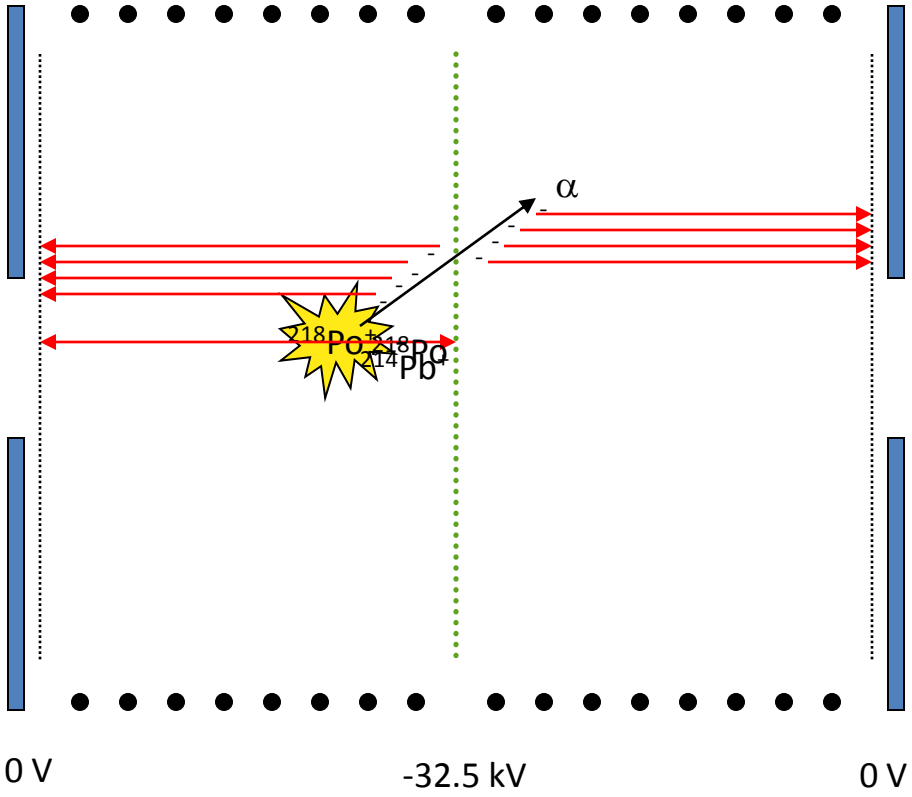


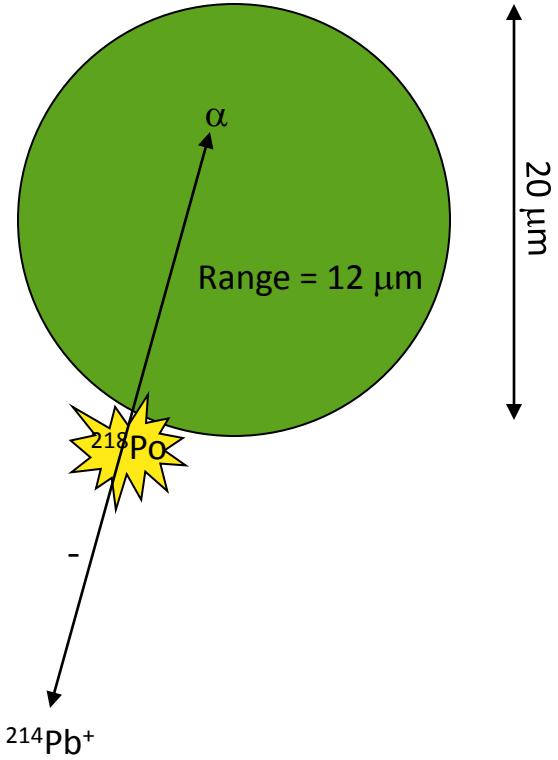


Radon Progeny



Radon Progeny Recoils (RPR)

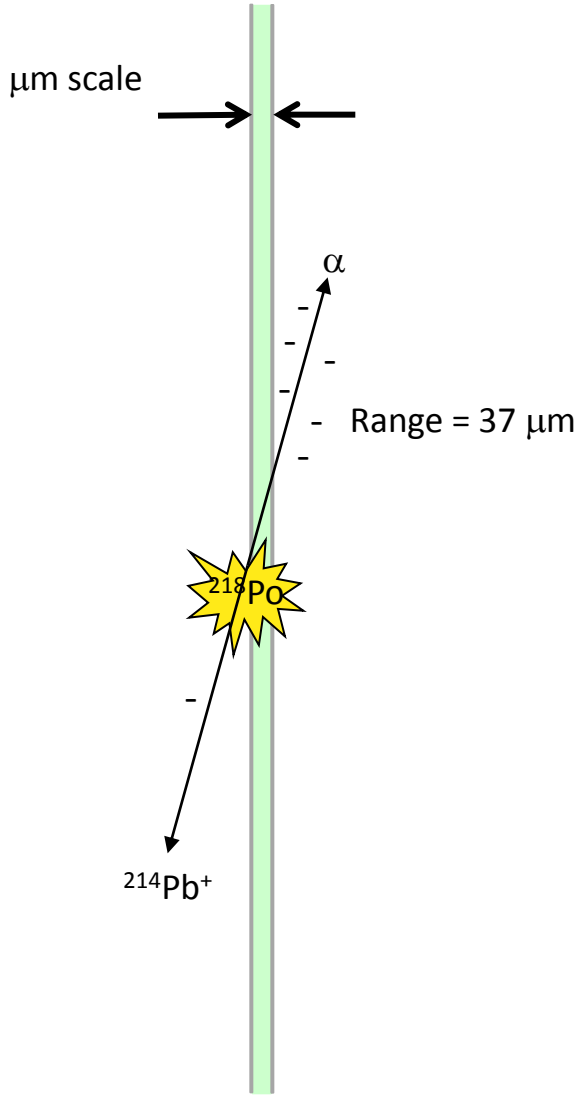




AstroPle, **28**, (2007) 409.

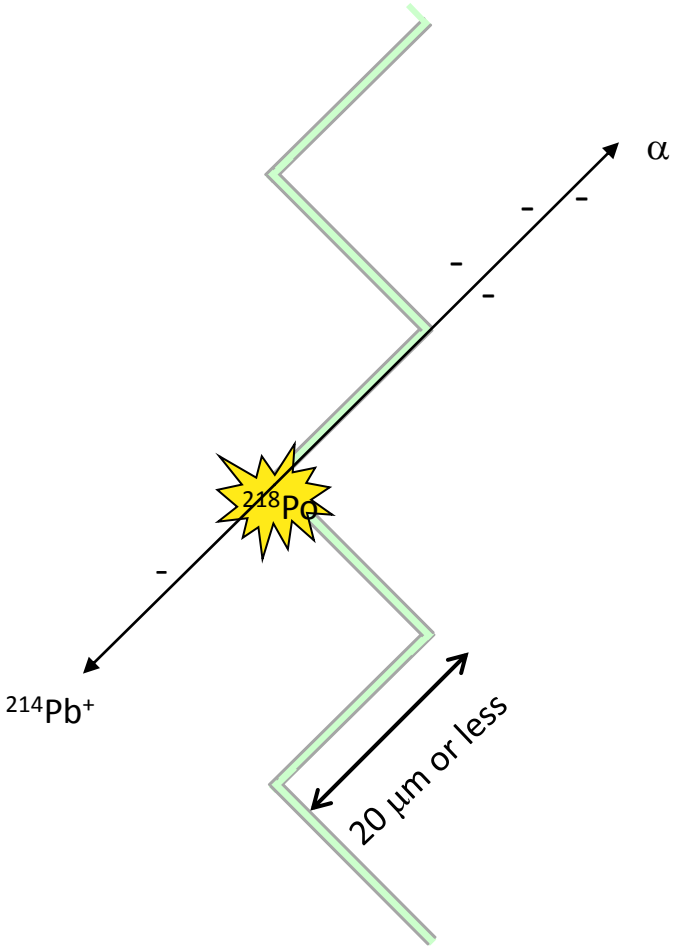
The solution – Part I

Give the alphas few places to hide in an aluminized Mylar thin film.

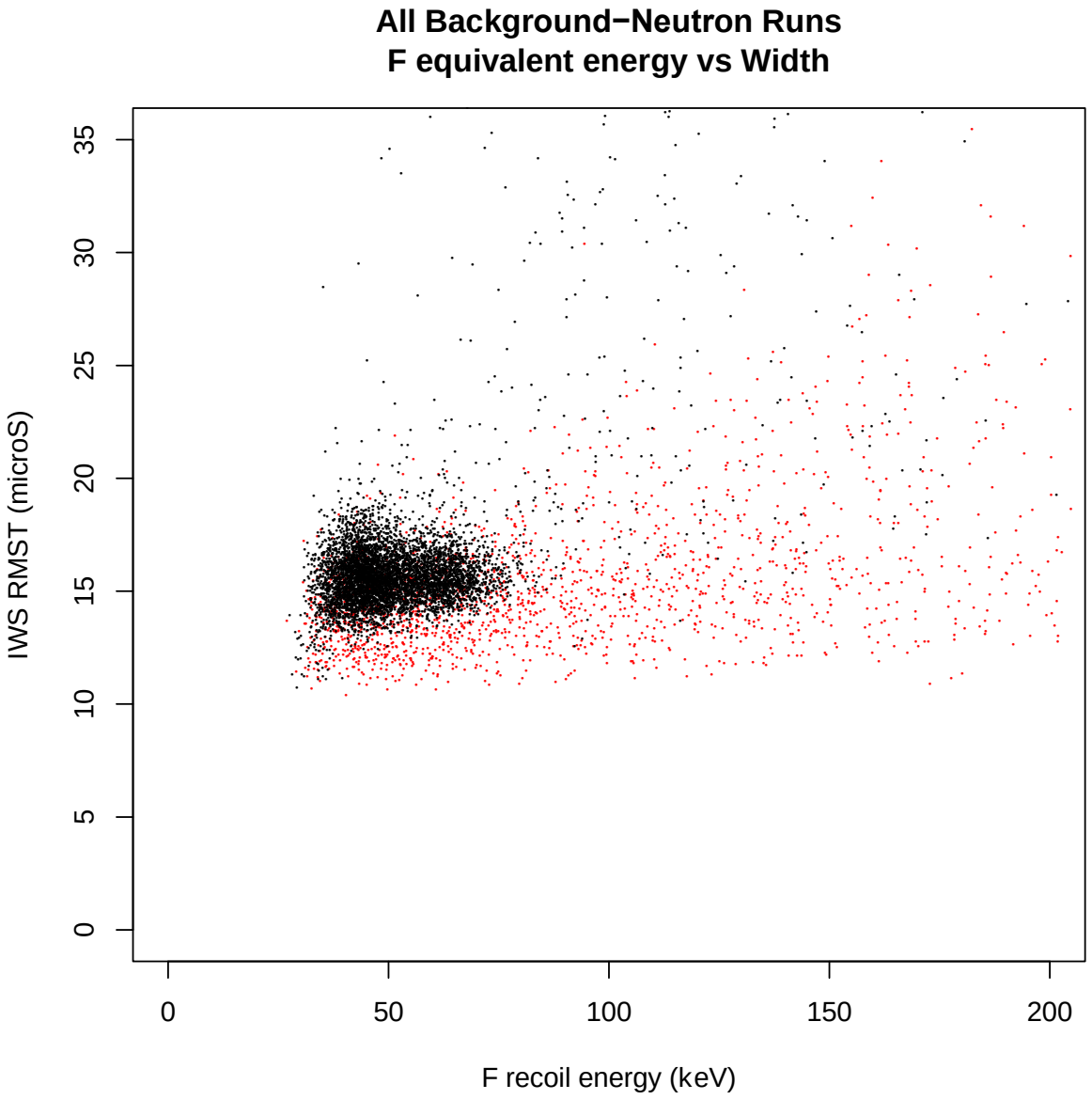


The solution – Part II

Give the alphas **no** place to hide in a **texturized** aluminized Mylar thin film.



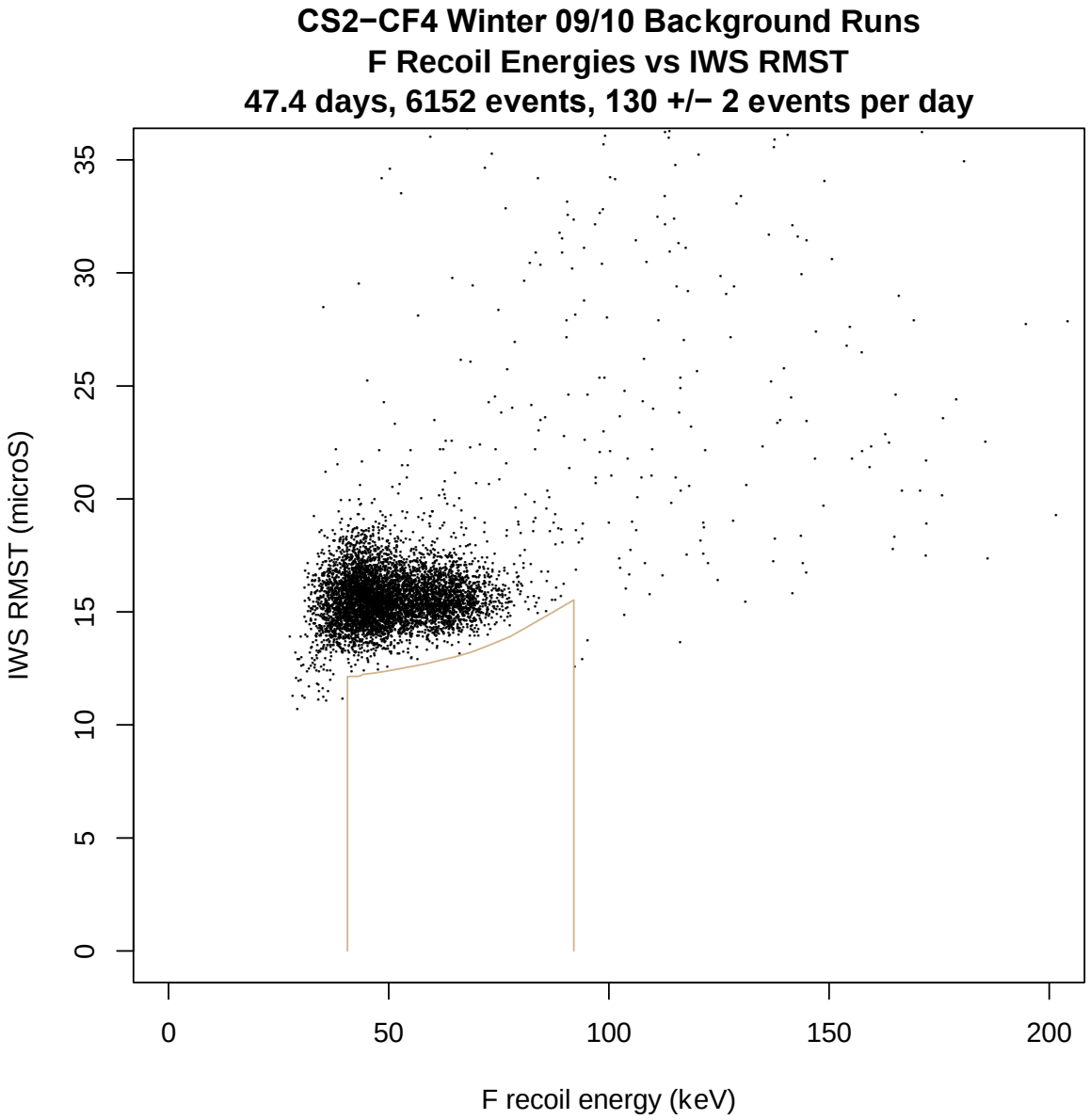
DRIFT-IId Data



- Diffusion of the RPRs from the central cathode increases their width
- Use width as a crude discrimination parameter
- Black = Background
- Red = Neutron recoils

AstroPle, **35**, (2012) 397.

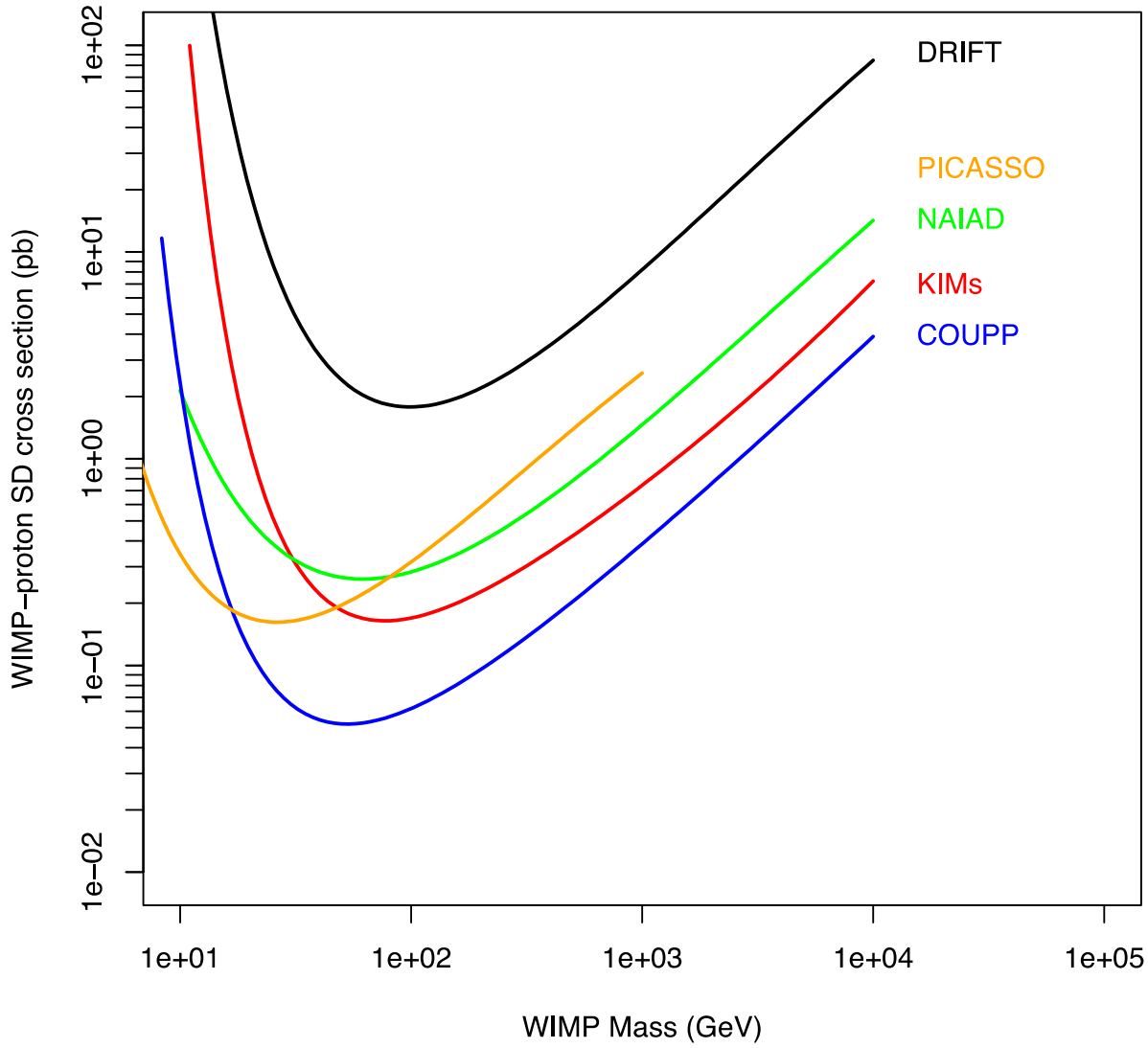
DRIFT-IId Data



- Select a signal window
- Unfortunately for 100 GeV WIMPs the signal window => 8% efficiency of events passing the cuts

AstroPle, **35**, (2012) 397.

DRIFT-IId Spin-Dependent WIMP Limits



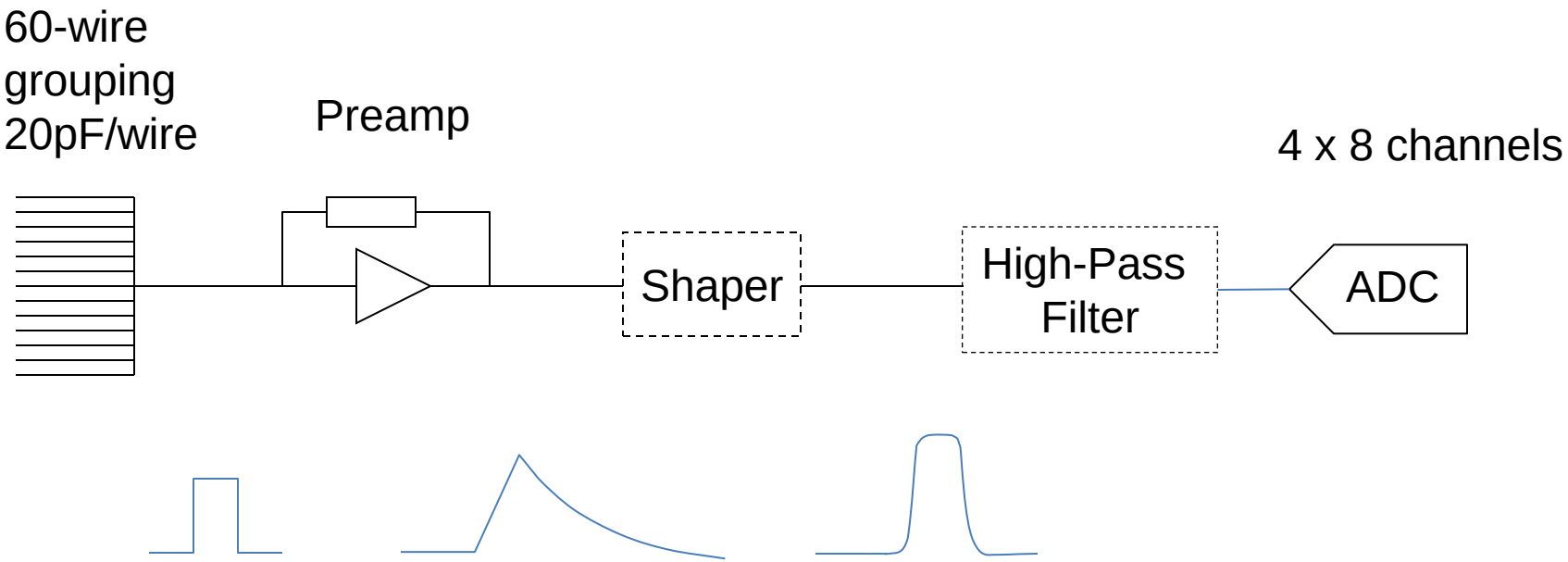
AstroPle, **35**, (2012) 397.

Present Background Suppression

High energy alphas	⇒	Suppression based on track length.
Neutrons	⇒	Material with low U content. Good shielding.
Gammas	⇒	Trigger with energy threshold above gammas.
Radon Progeny Recoils (RPR)	⇒	Radon reduction. New thin film texturized cathode.
Low energy alphas	⇒	New thin film texturized cathode.

- All of our unsuppressed backgrounds are due to RPR's and low energy alphas originating from the cathode.
- Steps are taken to reduce Radon emission by systematically measuring every components.
- Thin film texturized cathode is about to be implemented.

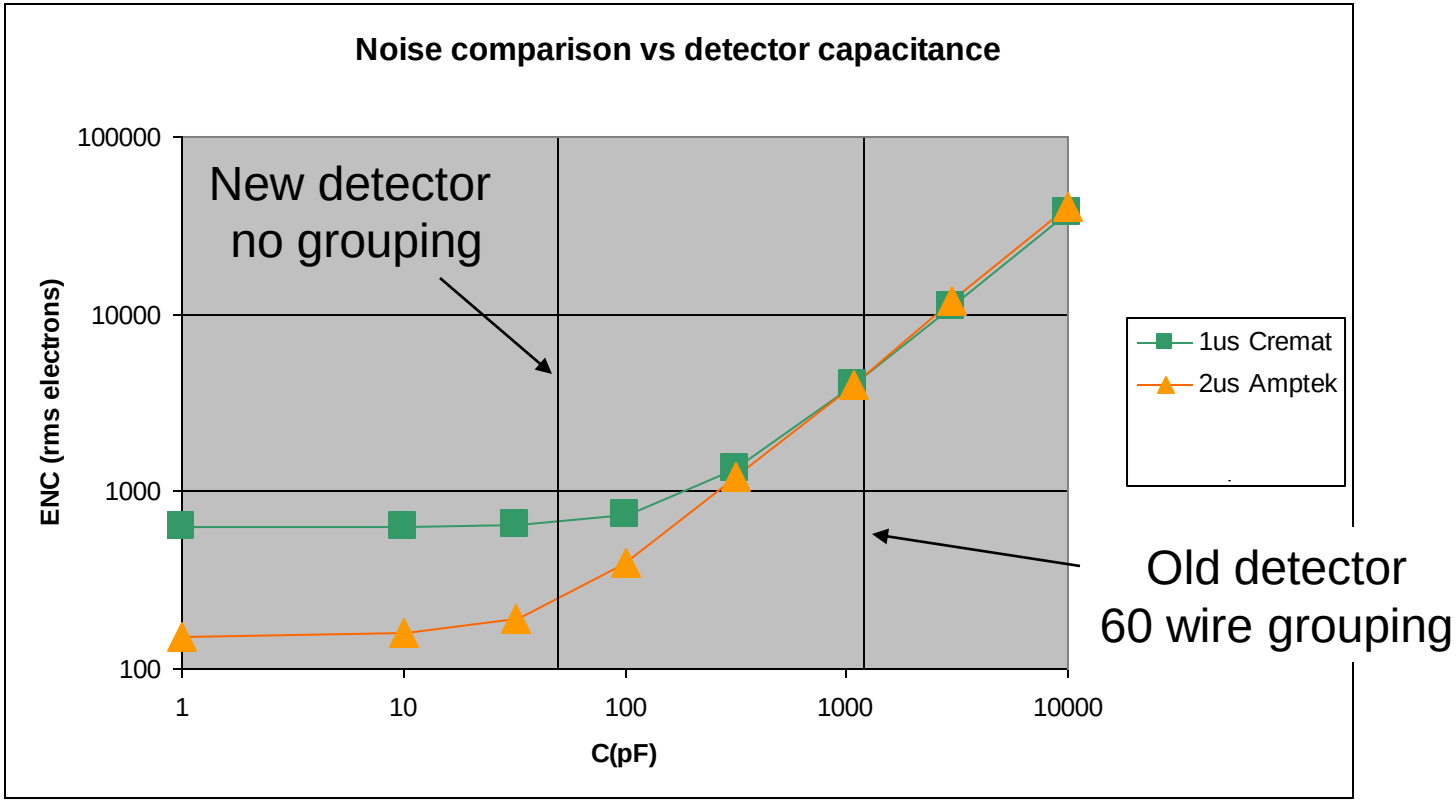
Present Electronics on DRIFT-IId



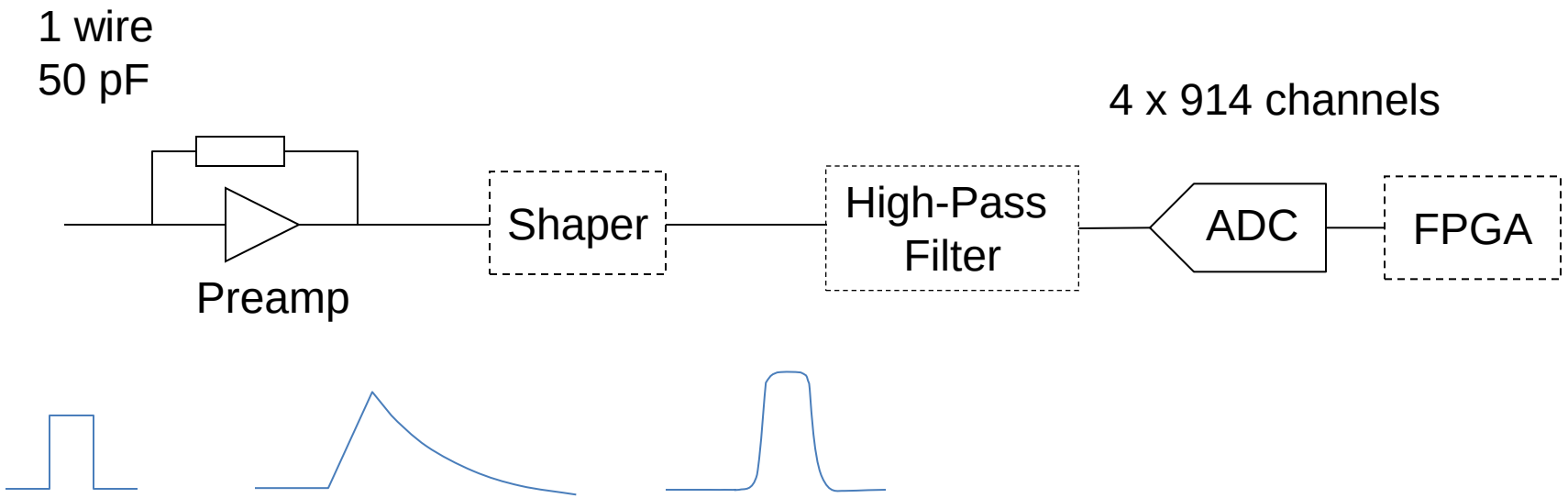
Shaping time = 4µs
C_{det} = 20pF x 60 =1200 pF
enc = 3500 e^- RMS

- Triggers if any channel exceeds threshold
- All 36 channels are saved.
- Typical event rate ~ 1Hz
- ACQ = 1MHz

Preamp Thermal noise vs C_{det}



New Ideal Electronics on DRIFT-IIe



Shaping time = 1µs
C_{det} = 50pF
enc < 1000 e^- RMS

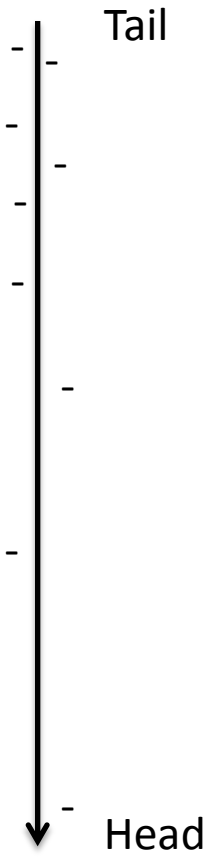
- Triggers if any channel exceeds threshold
- Only selected channels are saved.
- ACQ ≥ 1MHz
- ~ 1800 channels

Benefits of new low-noise electronics on DRIFT-IIe

- Signal/noise increased by a factor 2 or 3. (Taking into account C_{det} and gas gain.)
  - Increased efficiency to detect WIMPS
  - Gamma detection and suppression.
  - Better head-tail identification.
  - Improved track direction measurement
  - Operation at lower gain with more CF_4 content

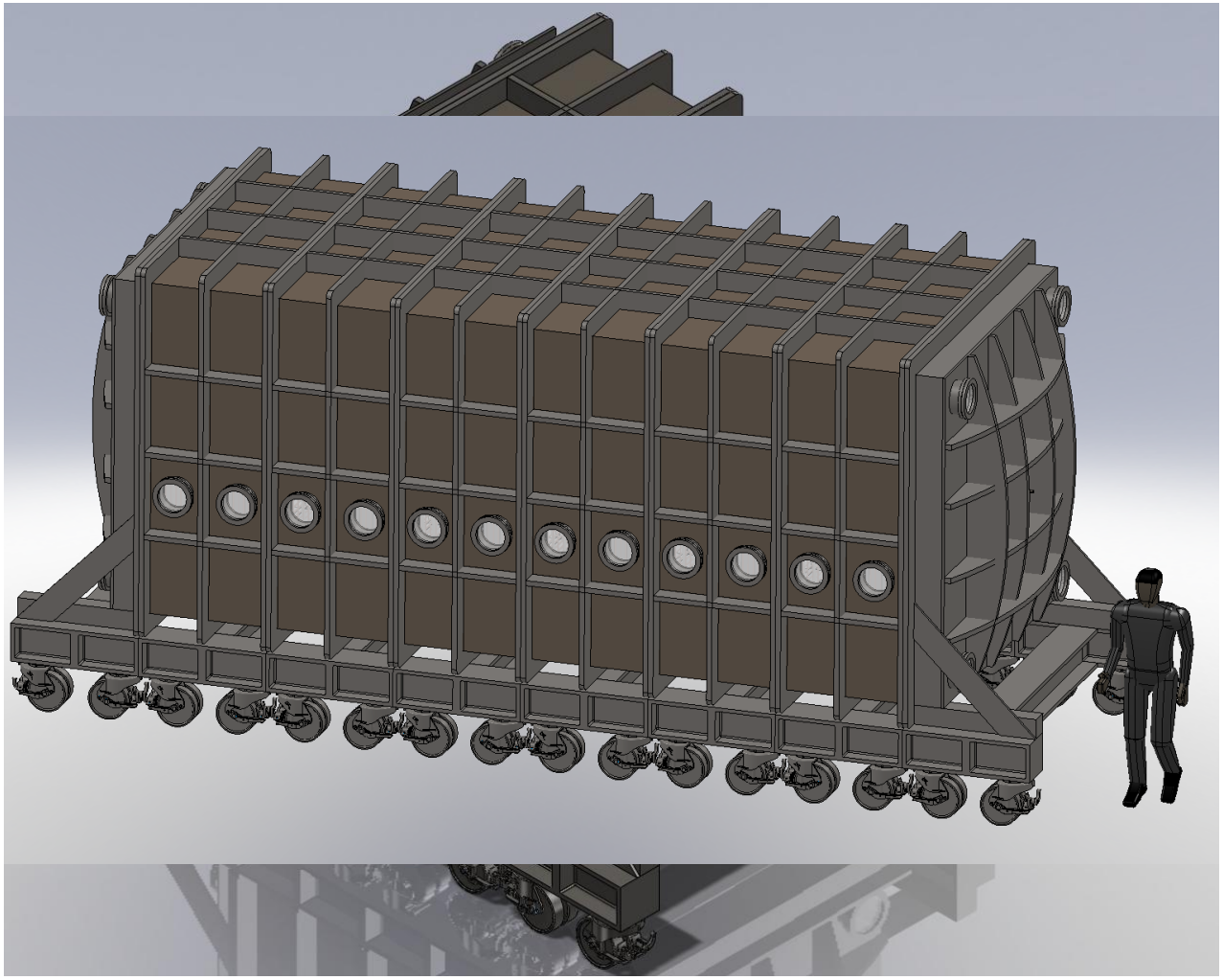
- Every wire is monitored. No grouping.
  - Edge veto in x.
  - Veto of Radon progeny plated on cathode without losing excessive fiducial volume.
  - Defective channels can be ignored; less down-time in repairs.
  - Proof of concept that every wire monitoring will be possible on DRIFT-III

Head – Tail detection



DRIFT-III

- Readout planes 4x bigger than DRIFT-II
- Same drift distance
- DRIFT-IIIa would have 10x the volume of a DRIFT-II class detector.
- Modular



Conclusion

- DRIFT-IId is now operating in Boulby.
- Negative ion drift to limit diffusion using CS2
- 30-10 Torr of CS2-CF4 to optimize for spin-dependent limits, 139 g target mass.
- Upgrade to DRIFT-IIe is underway.
- New MWPC design
- New, clean, texturized thin film cathode.
- Exploring possibilities of single wire readout electronics.
- DRIFT-IIe is a relatively cheap, clean, stable and scalable technology.